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*Information*

# Probability of Coronary Heart Disease Developing

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IN THE FRAMINGHAM STUDY a sample of adults has been followed since 1948 in order to investigate the development of cardiovascular disease. The sample is composed of several thousand men and women who live in Framingham, Massachusetts. Biennial clinical examinations provide information about the characteristics of persons in the study both before and after the onset of cardiovascular disease. The investigators in the Framingham study have sought to determine those characteristics that are associated with subsequent development of heart disease.

The data collected provided the basis for estimating values in multiple logistic functions using the Duncan-Walker method. A multiple logistic function yields a person's estimated risk of disease given his or her values on certain clinical characteristics called risk factors.

In 1973 the American Heart Association published the *Coronary Risk Handbook*[1] based on a particular set of these logistic functions. This pamphlet was designed for easy use by physicians and consists of nearly 100 tables. A physician can determine a patient's risk that heart disease will develop within the next six years by locating on the pertinent table risk factors for the patient's age, systolic blood pressure, serum cholesterol, cigarette smoking, presence or absence of glucose intolerance and presence or absence of left ventricular hypertrophy shown on an electrocardiogram (ECG).

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The charts presented in Figures 1 and 2 were designed to be used in place of the tables in the *Coronary Risk Handbook*. They are less cumbersome to use and also indicate the relative importance of the factors. The charts and the handbook are mathematically equivalent as they are both derived from the same set of multiple logistic functions. However, the chart probabilities may be slightly less accurate than those in the handbook.

## Definition of Risk Factors

The following definitions of the risk factors are taken from the *Coronary Risk Handbook:*

- *Systolic blood pressure* (SBP)—given in millimeters of mercury. Casual pressure taken with the patient seated.
- *Serum cholesterol* (chol)—given in milligrams per deciliter as measured by the Abell-Kendall method. Correction is necessary if another laboratory method is used.
- *Left ventricular hypertrophy* (LVH)—as evaluated by ECG, is determined by the finding of tall R waves in leads reflecting potentials from the left ventricle, accompanied by S-T depression or T-wave inversion. Other ECG abnormalities (including intraventricular conduction disturbance, nonspecific S-T depression and T-wave inversion abnormalities) carry an excess risk of a similar magnitude.
- *Smoking* (cig)—refers to current cigarette-smoking habit. The charts do not take into account intensity of smoking habit (packs per day per number of years) and contrast only smokers versus nonsmokers.
- *Glucose intolerance* (glu)—as evidenced by diabetes, trace or more of sugar in the urine, or a casual (nonfasting) whole blood glucose level of 120 mg per dl or greater.

## Examples

For the given example, Table 1 presents a calculation of the probability of coronary heart disease developing in men according to the charts, and the associated probability listed in the *Coronary Risk Handbook*. The calculation for women is displayed in Table 2.

## Comments

The regression coefficient for cigarette smoking in women is so small that smoking adds no points

ABBREVIATIONS USED IN TEXT

ECG = electrocardiogram
HDL = high-density lipoproteins
SBP = systolic blood pressure

to a woman's risk score. This result may be illuminated somewhat by examination of the relationship of smoking to various forms of coronary heart disease. Women with angina pectoris constitute most of the women who are designated as having coronary heart disease. Data from the Framingham study do not indicate increased incidence of angina pectoris among women who smoke. Trends in the data suggest, however, that smoking may be associated with an increased incidence of myocardial infarction in women 45 to 64 years old.[2] Thus the lack of points for smoking reflects its nonassociation with angina and may mask its possible association with the more serious condition of myocardial infarction. Had analogous charts been compiled to compute the probability of a myocardial infarction, it would be expected that one or two points might have been assigned to cigarette smoking.

To understand further why there are no points assigned to cigarette smoking, it is important to realize that this simply indicates that knowledge of the patient's smoking habit in the presence of knowledge of the other risk factors does not aid in the *prediction* of heart disease. While this may be due to the lack of a relationship between smoking and heart disease, such is not necessarily the case as illustrated by the following situation. Suppose cigarette smoking, acting alone or in combination with some other factor, has a deleterious effect on one or several of the other risk factors. Under this circumstance, the impact of smoking may be expressed almost entirely through the action of those factors affected by smoking. Thus

## Calculation of Probability

| Points | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SBP | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 |
| CIG | No | | | | Yes | | | | | | |
| LVH | No | | | | | | Yes | | | | |
| GLU | No | | Yes | | | | | | | | |

**Enter Points (in gray) for**

_____ Systolic Blood Pressure
\+ _____ Cigarette Smoking
\+ _____ Left Ventricular Hypertrophy
\+ _____ Glucose Intolerance
\+ _____ Age/Serum Cholesterol
= _____ Total Points → Probability

| Chol \ Age | 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 165 | 3 | 6 | 9 | 11 | 14 | 16 | 18 | 19 | 23 | 26 | 27 | 27 |
| 180 | 5 | 8 | 10 | 13 | 15 | 17 | 19 | 20 | 24 | 26 | 27 | 27 |
| 195 | 7 | 9 | 12 | 14 | 16 | 18 | 20 | 21 | 24 | 26 | 27 | 27 |
| 210 | 8 | 11 | 13 | 15 | 17 | 19 | 21 | 22 | 25 | 27 | 27 | 27 |
| 225 | 10 | 12 | 15 | 17 | 19 | 20 | 22 | 23 | 26 | 27 | 28 | 27 |
| 240 | 11 | 14 | 16 | 18 | 20 | 21 | 23 | 24 | 27 | 28 | 28 | 27 |
| 255 | 13 | 15 | 17 | 19 | 21 | 23 | 24 | 25 | 27 | 28 | 28 | 27 |
| 270 | 15 | 17 | 19 | 21 | 22 | 24 | 25 | 26 | 28 | 29 | 28 | 26 |
| 285 | 16 | 18 | 20 | 22 | 24 | 25 | 26 | 27 | 29 | 29 | 28 | 26 |
| 300 | 18 | 20 | 22 | 23 | 25 | 26 | 27 | 28 | 29 | 29 | 28 | 26 |
| 315 | 20 | 22 | 23 | 25 | 26 | 27 | 28 | 29 | 30 | 30 | 29 | 26 |

| TP | Prob | TP | Prob | TP | Prob |
|---|---|---|---|---|---|
| 5 | .003 | 20 | .021 | 35 | .13 |
| 6 | .004 | 21 | .024 | 36 | .14 |
| 7 | .004 | 22 | .028 | 37 | .16 |
| 8 | .005 | 23 | .031 | 38 | .17 |
| 9 | .006 | 24 | .035 | 39 | .19 |
| 10 | .006 | 25 | .040 | 40 | .21 |
| 11 | .007 | 26 | .045 | 41 | .23 |
| 12 | .008 | 27 | .050 | 42 | .25 |
| 13 | .009 | 28 | .057 | 43 | .28 |
| 14 | .010 | 29 | .064 | 44 | .30 |
| 15 | .012 | 30 | .071 | 45 | .33 |
| 16 | .013 | 31 | .080 | 46 | .36 |
| 17 | .015 | 32 | .090 | 47 | .39 |
| 18 | .017 | 33 | .100 | 48 | .42 |
| 19 | .019 | 34 | .11 | 49 | .45 |

Left Ventricular Hypertrophy — as evaluated by electrocardiogram (ECG).

Glucose Intolerance — as manifested by diabetes, or a trace or more of sugar in the urine, or a non-fasting whole blood glucose level of 120 mg% or greater.

**Figure 1.—Probability of coronary heart disease developing in six years, men (aged 35-70). (Compiled by Erica Brittain at Stanford University, 1979, from multiple logistic functions in *The Framingham Study.*[2])**

the lack of points for smoking should not be viewed as an exoneration of smoking as an agent of coronary heart disease in women.

Since publication of the *Coronary Risk Handbook,* it has been reported that low levels of high-density lipoproteins (HDL) are associated with increased incidence of coronary heart disease. Kannel and associates[3] have proposed a simple way to include HDL in the assessment of coronary risk. There are no Framingham data on HDL for those younger than 50 years, so that the use of this method relies on the assumption that the relationship between HDL and coronary heart disease remains constant regardless of age. If the HDL value is known, determination of the risk of heart disease obtained by the charts can be refined by multiplying this risk by the appropriate "multiplier" listed in Table 3. If the charts assign a 0.14 probability of heart disease developing in a man whose HDL value is known to be 40, a more accurate assessment of his risk is

$$(0.14 \times 1.22) = 0.17.$$

## Construction of Charts

The estimated risk is a function of $\Sigma \hat{\beta}_i x_i$ where $\hat{\beta}_i$ is the estimated regression coefficient and $x_i$ is the value of the $i$-th risk factor in the logistic function

$$\text{estimated risk} = \frac{1}{1+\exp\,(-\hat{a}-\Sigma\hat{\beta}_i x_i)}.$$

The regression coefficients are published in section 27 of *The Framingham Study.*[4]

The objective of the charts is to reproduce $\Sigma \hat{\beta}_i x_i$ with a simple scoring system. This is achieved by assigning points to specified values of risk factors. Points are assigned as follows:

$$\text{point}_i = (\hat{\beta}_i x_i \times \text{scale factor}) - \text{translation factor}_i.$$

The scale factor and translation factors are chosen to give the charts certain desirable properties. Once the point values are obtained, $\Sigma \hat{\beta}_i x_i$ can be expressed as

$$\Sigma \hat{\beta}_i x_i = \frac{\Sigma\,(\text{point}_i + \text{translation factor}_i)}{\text{scale factor}}.$$

Assignment of a point value to a systolic blood

## Calculation of Probability

| Points | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| SBP | 100 | 110 | 120 | 130 | 140 | 150 | 160 | 170 | 180 | 190 | 200 |
| LVH | No | | | Yes | | | | | | | |
| GLU | No | | | Yes | | | | | | | |

Note: No points added for Smoking

Enter Points (in gray) for

____ Systolic Blood Pressure
\+ ____ Left Ventricular Hypertrophy
\+ ____ Glucose Intolerance
\+ ____ Age/Serum Cholesterol
= ____ Total Points → Probability

| Chol | Age 36 | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 55 | 60 | 65 | 70 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 165 | 0 | 2 | 4 | 5 | 7 | 9 | 10 | 12 | 15 | 18 | 20 | 21 |
| 180 | 1 | 3 | 4 | 6 | 8 | 9 | 11 | 12 | 16 | 18 | 20 | 22 |
| 195 | 2 | 3 | 5 | 7 | 9 | 10 | 12 | 13 | 16 | 19 | 21 | 22 |
| 210 | 3 | 4 | 6 | 8 | 10 | 11 | 13 | 14 | 17 | 19 | 21 | 22 |
| 225 | 4 | 5 | 7 | 9 | 10 | 12 | 13 | 15 | 17 | 20 | 21 | 23 |
| 240 | 4 | 6 | 8 | 10 | 11 | 13 | 14 | 15 | 18 | 20 | 22 | 23 |
| 255 | 5 | 7 | 9 | 11 | 12 | 13 | 15 | 16 | 19 | 21 | 22 | 23 |
| 270 | 6 | 8 | 10 | 11 | 13 | 14 | 16 | 17 | 19 | 21 | 23 | 24 |
| 285 | 7 | 9 | 11 | 12 | 14 | 15 | 16 | 17 | 20 | 22 | 23 | 24 |
| 300 | 8 | 10 | 12 | 13 | 15 | 16 | 17 | 18 | 21 | 22 | 24 | 24 |
| 315 | 9 | 11 | 13 | 14 | 15 | 17 | 18 | 19 | 21 | 23 | 24 | 25 |

| TP | Prob | TP | Prob | TP | Prob |
|---|---|---|---|---|---|
| 5 | .002 | 17 | .014 | 29 | .081 |
| 6 | .003 | 18 | .016 | 30 | .093 |
| 7 | .003 | 19 | .019 | 31 | .11 |
| 8 | .004 | 20 | .022 | 32 | .12 |
| 9 | .004 | 21 | .025 | 33 | .14 |
| 10 | .004 | 22 | .029 | 34 | .16 |
| 11 | .006 | 23 | .034 | 35 | .18 |
| 12 | .007 | 24 | .040 | 36 | .20 |
| 13 | .008 | 25 | .046 | 37 | .23 |
| 14 | .009 | 26 | .053 | 38 | .26 |
| 15 | .010 | 27 | .061 | 39 | .29 |
| 16 | .012 | 28 | .071 | 40 | .32 |

Left Ventricular Hypertrophy — as evaluated by electrocardiogram (ECG).

Glucose Intolerance — as manifested by diabetes, or a trace or more of sugar in the urine, or a non-fasting whole blood glucose level of 120 mg% or greater.

**Figure 2.**—Probability of coronary heart disease developing in six years, women (aged 35-70). (Compiled by Erica Brittain at Stanford University, 1979, from multiple logistic functions in *The Framingham Study.*[2])

TABLE 1.—*Example Using Chart for Men*

| *Characteristic* | *Value* | *Points* |
|---|---|---|
| Systolic blood pressure | 150 | 5 |
| Cigarette smoking | yes | 4 |
| Left ventricular hypertrophy | no | 0 |
| Glucose intolerance | no | 0 |
| Age/serum cholesterol | 50/285 | 27 |
| TOTAL | | 36 |

Probability: 0.14
*Coronary Risk Handbook* probability: 0.134

TABLE 2.—*Example Using Chart for Women*

| *Characteristic* | *Value* | *Points* |
|---|---|---|
| Systolic blood pressure | 120 | 2 |
| Left ventricular hypertrophy | no | 0 |
| Glucose intolerance | no | 0 |
| Age/serum cholesterol | 50/210 | 14 |
| TOTAL | | 16 |

Probability: 0.012
*Coronary Risk Handbook* probability: 0.012 (smoker)
0.012 (nonsmoker)

TABLE 3.—*Multiplier for High-density Lipoprotein Cholesterol Level**

| *High-density Lipoprotein Cholesterol* | *Men mg/dl* | *Women mg/dl* |
|---|---|---|
| 30 | 1.82 | .... |
| 35 | 1.49 | .... |
| 40 | 1.22 | 1.94 |
| 45 | 1.00 | 1.55 |
| 50 | 0.82 | 1.25 |
| 55 | 0.67 | 1.00 |
| 60 | 0.55 | 0.80 |
| 65 | 0.45 | 0.64 |
| 70 | .... | 0.52 |

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pressure of 140 mm of mercury is used for illustration. The scale factor 8.036 is chosen because $\hat{\beta}$ for SBP is $0.0124 = (10 \times 8.036)^{-1}$. This produces a one-point increase for each added 10 mm of systolic blood pressure. The translation factor is chosen to be 10 so that a blood pressure of 100 would correspond to 0 points:

$$\text{point} = [(0.01244 \times 140) \times 8.036] - 10 = 14 - 10 = 4.$$

Thus a systolic blood pressure of 140 is assigned 4 points.

A common scale factor must be used for all risk factors. It was felt that choosing a scale factor based on systolic blood pressure gave the most pleasing presentation.

## Summary

Based on the multiple logistic functions estimated from the Framingham study data, charts are compiled for calculating the probability of coronary heart disease developing in six years by men and women.

### REFERENCES

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